

CLAIMS

What is claimed is:

1. An apparatus for recirculating a reactant fluid stream of a fuel cell system having a fuel cell stack with an inlet stream and an exhaust stream, the apparatus comprising:
 - a common suction chamber fluidly connected to a suction inlet configured to receive a recirculated flow from the exhaust stream of the fuel cell stack;
 - a low-flow nozzle positioned in the common suction chamber and fluidly connected to a low-flow motive inlet configured to receive a first motive flow from a reactant source of the fuel cell stack;
 - a low-flow diffuser fluidly connected to a discharge outlet configured to provide the inlet stream to the fuel cell stack;
 - a high-flow nozzle positioned in the common suction chamber and fluidly connected to a high-flow motive inlet configured to receive the first motive flow from the reactant source; and
 - a high-flow diffuser fluidly connected to the discharge outlet.
2. The apparatus of claim 1, wherein the common suction chamber is substantially cylindrical.
3. The apparatus of claim 1, further comprising:
 - a low-flow one-way check valve for preventing flow regress through the low-flow diffuser; and
 - a high-flow one-way check valve for preventing flow regress through the high-flow diffuser.
4. The apparatus of claim 1, wherein:

the low-flow nozzle and low-flow diffuser are configured to entrain the recirculated flow and provide the inlet stream at low-load conditions; and

the high-flow nozzle and high-flow diffuser are configured to entrain the recirculated flow and provide the inlet stream at high-load conditions.

5. The apparatus of claim 4, further comprising:

a low-flow one-way check valve for preventing flow regress through the low-flow diffuser; and

a high-flow one-way check valve for preventing flow regress through the high-flow diffuser.

6. The apparatus of claim 1, further comprising:

an ultra-low-flow nozzle positioned in the common suction chamber and fluidly connected to an ultra-low-flow motive inlet configured to receive a second motive flow from the reactant source; and

an ultra-low-flow diffuser fluidly connected to the discharge outlet.

7. The apparatus of claim 6, wherein the common suction chamber is substantially cylindrical.

8. The apparatus of claim 6, further comprising:

a low-flow one-way check valve for preventing flow regress through the low-flow diffuser; and

a high-flow one-way check valve for preventing flow regress through the high-flow diffuser.

9. The apparatus of claim 8, further comprising an ultra-low-flow one-way check valve for preventing flow regress through the ultra-low-flow diffuser.

10. The apparatus of claim 6, wherein
the low-flow nozzle and low-flow diffuser are configured to entrain the recirculated flow and provide the inlet stream at low-load conditions;
the high-flow nozzle and high-flow diffuser are configured to entrain the recirculated flow and provide the inlet stream at high-load conditions; and
the ultra-low-flow nozzle and ultra-low-flow diffuser are configured to entrain a portion of the recirculated flow and provide a portion of the inlet stream at idle-load conditions.

11. The apparatus of claim 10, further comprising:
a low-flow one-way check valve for preventing flow regress through the low-flow diffuser; and
a high-flow one-way check valve for preventing flow regress through the high-flow diffuser.

12. The apparatus of claim 10, further comprising an ultra-low-flow one-way check valve for preventing flow regress through the ultra-low-flow diffuser.

13. An electric power generation system comprising
a fuel cell stack comprising a reactant stream inlet, a reactant stream outlet and at least one fuel cell;
a pressurized reactant supply;
a multiple ejector assembly, comprising:
a first motive flow inlet fluidly connected to the pressurized reactant supply,
a second motive flow inlet fluidly connected to the pressurized reactant supply,
a suction inlet, fluidly connected to the reactant stream outlet to receive a recirculated flow from the fuel cell stack, and

a discharge outlet, fluidly connected to the reactant stream inlet to provide an inlet stream to fuel cell stack;

a regulator, fluidly connected to, and interposed between, the pressurized reactant supply and the first and second motive flow inlets of the multiple jet ejector assembly, for regulating a first motive flow to the multiple jet ejector assembly; and

a first solenoid valve, fluidly connected to, and interposed between, the second motive flow inlet and the regulator.

14. An electric power generation system comprising:

a fuel cell stack comprising a reactant stream inlet, a reactant stream outlet and at least one fuel cell;

a pressurized reactant supply;

a multiple jet ejector assembly, comprising:

a first motive flow inlet fluidly connected to the pressurized reactant supply,

a second motive flow inlet fluidly connected to the pressurized reactant supply,

a suction inlet fluidly connected to the reactant stream outlet to receive a recirculated flow from the fuel cell stack, and

a discharge outlet, fluidly connected to the reactant stream inlet to provide an inlet stream to the fuel cell stack;

a regulator, fluidly connected to, and interposed between, the pressurized reactant supply and the first and second motive flow inlets of the multiple jet ejector assembly, for regulating a first motive flow to the multiple jet ejector assembly;

a first solenoid valve, fluidly connected to, and interposed between, the first motive flow inlet and the regulator;

a second solenoid valve, fluidly connected to, and interposed between, the second motive flow inlet and the regulator;

a by-pass line, fluidly connecting the pressurized reactant supply to the second motive flow inlet, for supplying a second motive flow to the multiple jet ejector assembly; and

a by-pass solenoid valve, fluidly connected to, and interposed in the bypass line between, the pressurized reactant supply and the second motive flow inlet.

15. The electric power generation system of claim 14, wherein:

the first motive flow inlet is fluidly connected to a first nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at high-load conditions; and

the second motive flow inlet is fluidly connected to a second nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at low-load conditions.

16. The electric power generation system of claim 14, wherein the regulator is a pressure control valve for regulating the pressure of the first motive flow to the multiple jet ejector assembly.

17. The electric power generation system of claim 16, further comprising a pressure transducer for detecting the pressure of the first motive flow to the multiple jet ejector assembly and for assisting in the operation of the first, second and by-pass solenoid valves.

18. The electric power generation system of claim 14, wherein the multiple jet ejector assembly further comprises a third motive flow inlet fluidly connected to the pressurized reactant supply.

19. The electric power generation system of claim 18, wherein:

the first motive flow inlet is fluidly connected to a first nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at high-load conditions;

the second motive flow inlet is fluidly connected to a second nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at low-load conditions; and

the third motive flow inlet is fluidly connected to a third nozzle and diffuser configured to entrain a portion of the recirculated flow and provide a portion of the inlet stream at idle-load conditions.

20. A method of operating the electric power generation system of claim 14, comprising:

during low-load operating conditions, opening the second solenoid valve and closing the first and by-pass solenoid valves, so that the first motive flow is directed to the second motive flow inlet; and

during high-load operating conditions, closing the second solenoid valve and opening the first and by-pass solenoid valves, so that the first motive flow is directed to the first motive flow inlet and the second motive flow is directed to the second motive flow inlet.

21. A method of operating the electric power generation system of claim 18, comprising:

during low-load operating conditions, opening the second solenoid valve and closing the first and by-pass solenoid valves, so that the first motive flow is directed to the second motive flow inlet;

during high-load operating conditions, closing the second solenoid valve and opening the first and by-pass solenoid valves, so that the first motive flow is directed to the first motive flow inlet and the second motive flow is directed to the second motive flow inlet; and

during all operating conditions, directing a third motive flow from the pressurized reactant supply to the third motive flow inlet.

22. An electric power generation system comprising:

a fuel cell stack, comprising a first reactant stream inlet configured to receive a first inlet stream, a second reactant stream inlet configured to receive a second inlet stream, a first reactant stream outlet and at least one fuel cell;

a pressurized reactant supply;

a multiple jet ejector assembly, comprising:

a suction inlet, fluidly connected to the first reactant stream outlet to receive a recirculated flow,

a discharge outlet, fluidly connected to the first reactant stream inlet to provide the first inlet stream,

a first motive flow inlet fluidly connected to the pressurized reactant supply, and

a second motive flow inlet fluidly connected to the pressurized reactant supply;

a first pressure regulator, fluidly connected to, and interposed between, the pressurized reactant supply and the first motive flow inlet, for regulating the pressure of a first motive flow to the first motive flow inlet, wherein the first pressure regulator is configured to maintain the pressure of the first inlet stream, in relation to the pressure of the second inlet stream, at a substantially constant first pressure differential; and

a second pressure regulator, fluidly connected to, and interposed between, the pressurized reactant supply and the second motive flow inlet, for regulating the pressure of a second motive flow to the second motive flow inlet, wherein the second pressure regulator is configured to maintain the pressure of the first inlet stream, in relation to the pressure of the second inlet stream, at a substantially constant second pressure differential,

wherein the first pressure differential is different from the second pressure differential.

23. The electric power generation system of claim 22, wherein:

the first motive flow inlet is fluidly connected to a first nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at high-load conditions;

the second motive flow inlet is fluidly connected to a second nozzle and diffuser configured to entrain the recirculated flow and provide the inlet stream at low-load conditions; and

the first pressure differential is less than the second pressure differential.

24. A pressure regulator, comprising:

a first reference chamber, configured to be fluidly connected to a reference feedback line of a first fluid;

a second reference chamber, configured to be fluidly connected to a reference feedback line of a second fluid;

a flexible membrane, fluidly separating the first and second reference chambers, biased to be in a state of equilibrium whenever the pressure of the first fluid, in relation to the pressure of the second fluid, is at a desired pressure differential;

a regulator inlet, configured to be fluidly connected to a pressurized reactant supply;

a first regulator outlet;

a second regulator outlet;

a first passage, fluidly connecting the regulator inlet and the first regulator outlet;

a second passage, fluidly connecting the regulator inlet and the second regulator outlet;

a first movable stem, configured to follow the movement of the flexible membrane, comprising a first plug configured to open and close the first passage depending on the position of the first movable stem; and

a second movable stem, configured to follow the movement of the first movable stem after the first movable stem has been displaced by the flexible membrane by a set distance, comprising a second plug configured to open and close the second passage depending on the position of the second movable stem.

25. The pressure regulator of claim 24, wherein the flexible membrane, the first movable stem and the second movable stem are arranged such that, as the pressure of the first fluid increases relative to the pressure of the second fluid, the flexible membrane depresses the first movable stem, thereby opening the first passage, and after having been displaced by the set distance, the first movable stem depresses the second movable stem, thereby opening the second passage.

26. The pressure regulator of claim 24, wherein
the second movable stem comprises an inner axial passage configured to allow movement of the first movable stem and to fluidly connect the regulator inlet and the first regulator outlet;

the first movable stem is configured to move inside the inner axial passage of the second movable stem and engage the second movable stem after having been displaced by the flexible membrane by the set distance.

27. An electric power generation system comprising:
a fuel cell stack, comprising a reactant stream inlet, a reactant stream outlet and at least one fuel cell;
a pressurized reactant supply;
a multiple jet ejector assembly, comprising:
a suction inlet, fluidly connected to the reactant stream outlet to receive a recirculated flow from the fuel cell stack,
a discharge outlet, fluidly connected to the reactant stream inlet to provide an inlet stream to the fuel cell stack,
a first inlet fluidly connected to the pressurized reactant supply,
and
a second inlet fluidly connected to the pressurized reactant supply;
and

the pressure regulator of claim 24, fluidly connected to, and interposed between, the pressurized reactant supply and the multiple jet ejector assembly,

wherein the first regulator outlet is fluidly connected to the first inlet of the multiple jet ejector assembly and the second regulator outlet is fluidly connected to the second inlet of the multiple jet ejector assembly.